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A Glasshouse as a Solar Energy Collector to Offset Heating Costs for Curing Onions

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The principle of using waste heat from industrial processes to offset fuel costs in protected cropping appears to be a practical proposition. The question is now posed "to what extent can the solar energy collected by a glasshouse be used to reduce fuel costs in curing onions for storage?"

Onions are harvested in early August (winter sown) and mid-September (spring sown) and stored in purpose-built stores for periods of up to six months. Before storage at low temperature the onions are "cured" by ventilating with air at 30°C for between 2 and 5 days.

A proposal to build a 0.1 ha ($\frac{1}{4}$ acre) glasshouse in association with an onion store near Boston, Lincs and to use solar energy so collected to aid the curing phase is examined.

The following assumptions are made:-

Area of glasshouse base	=	1000 m^2
Volume of glasshouse	=	2700 m^3
Fuel required to produce 1 KWH (Medium grade oil)	=	0.14 litre
Ventilation rate for curing at 30°C	=	425 $m^3 t^{-1} h^{-1}$
Specific heat of air	=	1.01 $Jg^{-1} {}^{o}C^{-1}$
Density of air (at 20°C)	=	1200gm^{-3}
Weight of onions in store	=	500 t
1 Kwh	=	3.6 x 10^6 joules

The energy required to raise the temperature of the ventilating air by 1°C for 500t of onions is:-

$$\frac{500 \times 425 \times 1200 \times 1.01}{3.6 \times 10^6}$$

$$= 71.5 \text{ kwh } {}^{o}C^{-1}$$

Estimated hourly temperatures for Cranwell were derived by fitting a cosine curve to average daily maximum and minimum temperatures (for an "average" day) and to average monthly maximum and average daily minimum temperatures (for a "hot" day). The energy required to raise the temperature of such ambient air to 30°C was calculated - see Table 1. This table shows that for an average August day the energy requirement for curing at 30°C is about 24.6 Mwh reducing to about 20.3 Mwh on a hot day. For September, the corresponding figures are 28 and 23 Mwh respectively.

An estimate of the amount of solar energy available to raise the air temperature inside a glasshouse was made from the Glasshouse Heating Program devised by S. Wass of Met O Bristol. Assuming that 54% of the total (outside) solar radiation is available for sensible heat, the average weekly contribution of solar energy is shown in Figure 1.

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We find that, on average, the solar energy contribution falls from about 17 Mwh per week in early August to about 8 Mwh per week in late September.

On 85% of occasions we might expect to have at least 14 Mwh per week in early August and at least 6 Mwh per week in late September (15% of occasions less than mean - 1 standard deviation).

The percentage fuel saving available from solar energy is summarised in Table 2.

Using a medium grade fuel oil yielding 60% of gross calorific value requires 0.14 litres to produce 1 kwh. The potential savings in hot spells in August and September are about 400 and 200 litres per day respectively or about £40 and £20 per day at fuel costs of 10p per litre.

It is tempting to argue that at very high radiation levels the savings could be greater. However, unless the high radiation is associated with comparatively low temperatures, the extra input is not used since the midday temperatures will already be close to 30°C and the system does not allow for storage of the extra energy.

Any comments or criticisms should be addressed to the author.

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Table 1

Estimated energy required to raise the temperature of 212500m^3h^{-1} of ambient air to 30°C on "average" and "hot" days in August and September

	Average				Hot			
	August		September		August		September	
Hour	Temp °C	Energy Mwh	Temp °C	Energy Mwh	Temp °C	Energy Mwh	Temp °C	Energy Mwh
00	13.3	1.194	11.7	1.308	14.5	1.108	13.2	1.201
01	12.5	1.251	11.1	1.351	13.2	1.201	12.1	1.280
02	11.9	1.294	10.5	1.394	12.3	1.266	11.1	1.351
03	11.4	1.330	10.0	1.430	11.6	1.316	10.3	1.409
04	11.2	1.344	9.7	1.451	11.2	1.344	9.8	1.444
05	11.3	1.337	9.5	1.466	11.3	1.337	9.5	1.466
06	11.7	1.308	9.6	1.459	11.9	1.294	9.6	1.459
07	12.5	1.251	10.2	1.416	13.2	1.201	10.7	1.380
08	13.6	1.173	11.4	1.330	15.0	1.073	12.7	1.237
09	14.9	1.080	12.9	1.223	17.1	.922	15.2	1.058
10	16.3	.980	14.6	1.101	19.2	.772	17.9	.865
11	17.7	.879	16.1	.994	21.3	.622	20.5	.679
12	18.8	.801	17.3	.908	23.1	.493	22.4	.543
13	19.6	.744	17.9	.865	24.3	.408	23.5	.465
14	20.0	.715	18.0	.858	25.0	.358	23.6	.458
15	20.1	.708	17.8	.872	25.1	.350	23.3	.479
16	19.9	.722	17.5	.894	24.7	.379	22.8	.515
17	19.4	.758	17.0	.930	24.0	.429	22.0	.572
18	18.8	.801	16.4	.972	23.1	.493	21.0	.644
19	18.0	.858	15.7	1.022	21.8	.586	19.9	.722
20	17.1	.922	14.9	1.080	20.4	.686	18.6	.815
21	16.1	.944	14.2	1.130	18.9	.794	17.2	.915
22	15.1	1.065	13.3	1.194	17.4	.901	15.9	1.008
23	14.2	1.130	12.5	1.251	15.9	1.008	14.5	1.108
Total		24.64		27.90		20.34		23.07

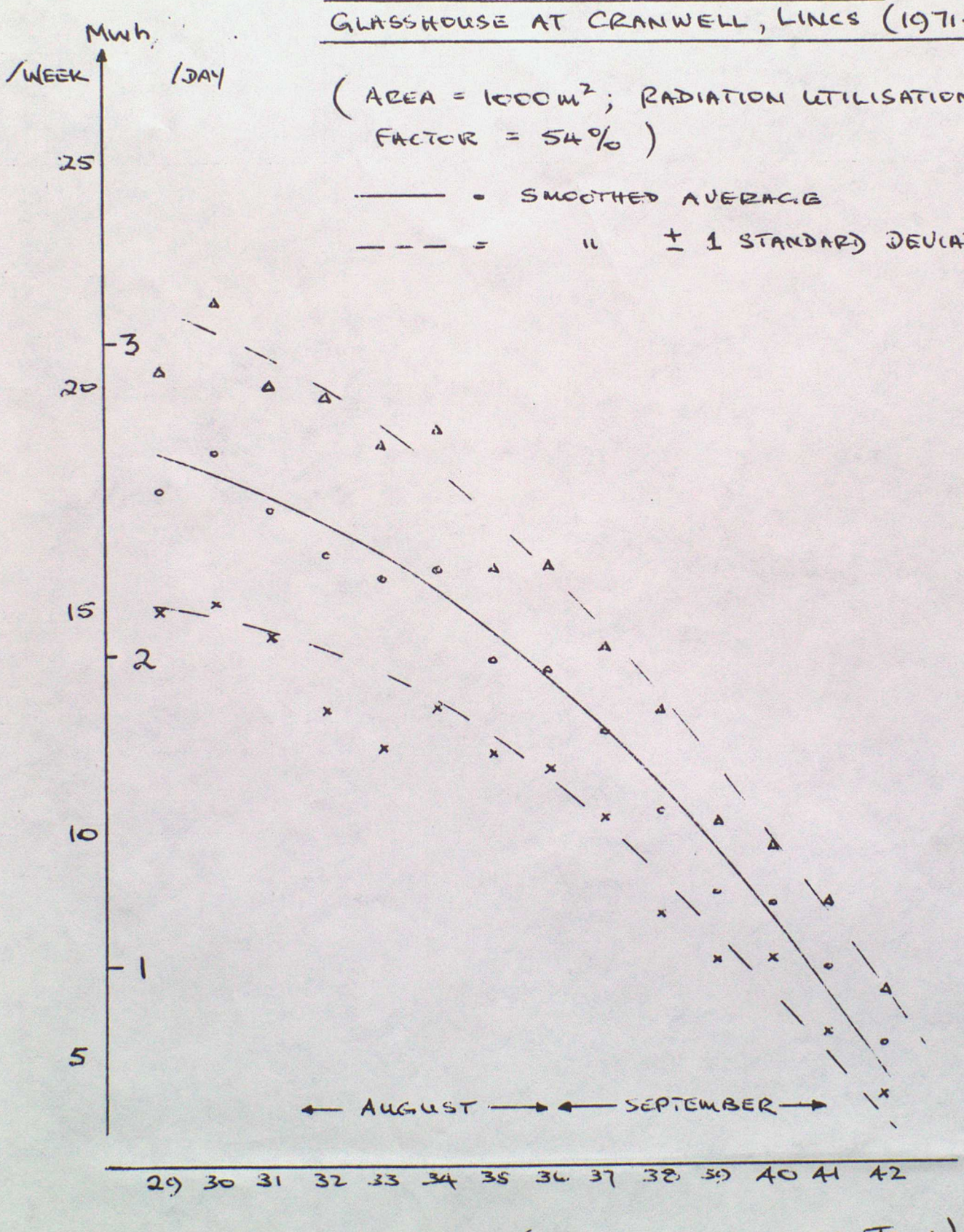
Table 2

Proportion of fuel used in curing onions which might be saved by utilising solar energy

		Energy Required Mwh d^{-1}	Solar Contribution Average Mwh d^{-1}	Solar Contribution Average per cent	85% Mwh d^{-1}	85% per cent
August	Average	24.64	2.43	9.9%	2.00	8.1%
	Hot	20.34	2.86*	14.1%	-	-
September	Average	27.90	1.14	4.1%	0.86	3.7%
	Hot	23.07	1.43*	6.2	-	-

* Using mean + 1 SD solar energy figure

AVERAGE SOLAR ENERGY INPUT TO A GLASSHOUSE AT CRANWELL, LINCS (1971-80)



(AREA = 1000 m^2 ; RADIATION UTILISATION FACTOR = 54%)

——— = SMOOTHED AVERAGE

— — — = " ± 1 STANDARD DEVIATION.

FIGURE 1